INTRODUCTION:

A. Overview of Dental Amalgam Procedures in Operative Dentistry:

1. Cavity Preparation Technique
2. Pulpal Protection with Varnishes, Liners, Bases and/or Bonding Systems
3. Amalgam Restoration (Product Selection, Dispensing, Trituration, Placement, Condensation, Carving, Burnishing, Finishing, Polishing)

B. Definitions and Terminology:

1. Amalgam = an ALLOY containing MERCURY as a MAJOR INGREDIENT
2. Dental Amalgam = an ALLOY of Hg with Ag-Sn
   a. Low Copper Dental Amalgam = Hg / Ag-Sn-(Cu)-(Zn)
   b. High Copper Dental Amalgam = Hg / Ag-Sn - Cu -(Zn)
      ...(or In or Pd substituted for Cu)
3. Dental Amalgam Alloy: an Ag-Sn ALLOY (Powder) to be MIXED with Hg

C. Dental Amalgam Alloy Powders:

1. Alloy Production:
   a. Melting/ Casting/ Commi nution ---> IRREGULAR Particles
      (1) Cast ingots are filed into powder on a lathe (Comminution)
      (2) Irregular Particles = Lathe cut = Filings
      (3) Particles are polycrystalline
      (4) Homogenization heat treatment to remove coring
      (5) Annealing heat treatment of filings to relieve cold work
   b. Melting/ Spray Atomization ---> SPHERICAL Particles

2. Alloy Packaging and Manipulation:
   a. Manual Trituration: (Trituration= Mixing; Amalgamation= Rx)
      Powder and Mercury ---> Mortar and Pestle
   b. Mechanical Trituration:
      Powder and Mercury ---> Capsule and Pestle ---> Amalgamator
      Pellet and Mercury ---> Capsule and Pestle ---> Amalgamator
      Powder and Mercury ---> Pre-Capsulated ---> Amalgamator

3. Mercury/Alloy Ratios:
   a. Decreased with time and advent of spherical alloy powders

![Mercury Levels in Dental Amalgam Graph]
4. Classification Methods for Dental Amalgam Alloys:
   a. Copper Content (of alloy overall):
      (1) Low Copper Alloys (Conventional) = 0-5 w/o
      (2) High Copper Alloys (Corrosion Resistant) = 12-30 w/o
   b. Particle Shape (and Size):
      (1) Irregular (= Lathe Cut = Filings = Comminuted): Reg, Fine, Micro
      (2) Spherical (invented by Duane Taylor)
   c. Number of Powder Particle Types:
      (1) One particle systems (= single composition alloys)
      (2) Two particle systems (= admixed alloys; two composition alloys)
   d. Presence of Zinc (of alloy):
      (1) Zinc Containing = 0.01-1 w/o
      (2) Zinc Free = <0.01 w/o

**LOW COPPER DENTAL AMALGAM ALLOYS:**

Classification:
(1) Irregular Particles (I)
(2) Spherical Particles (S)

Commercial Examples:
(1) New True Dentalloy 71Ag-26Sn-1.5Cu (I)
(2) Velvalloy ..................... (I)
(3) Caulk Spherical ............... (S)
(4) Shofu Spherical ............... (S)
(5) Kerr Spherical ............... (S)

**HIGH COPPER DENTAL AMALGAM ALLOYS:**

Classification:
(1) Irregular (I) = One Particle (Ternary = Ag-Sn-Cu)
(2) Irregular + Irregular (I+I) = Two Particle (Binary = Ag-Sn, Cu-Sn)
(3) Irregular + Spherical (I+S) = Two Particle (Binary = Ag-Sn, Cu-Sn)
(4) Spherical + Spherical (S+S) = Two Particle (Binary = Ag-Sn, Cu-Sn)
(5) Spherical (S) = One Particle (Ternary = Ag-Sn-Cu)

Commercial Examples:
(1) (J&J) Dispersalloy 69Ag-18Sn-12Cu-1Zn (I+S)
(2) (SS White) Kerr Tytin 59Ag-28Sn-13Cu (S)
(3) Kerr Sybraloy 41Ag-30Sn-28Cu-1?? (S)
(4) Cupralloy 62Ag-15Sn-23Cu (S+S)
(5) Optaloy II 70Ag-22Sn-8Cu+-Zn (I+S)
(6) Phasealloy ..................... (I+S)
(7) Aristalloy CR 59Ag-28Sn-13Cu (S)
(8) Indiloy 61Ag-24Sn-12Cu-3In (?)
(9) Micro II 70Ag-21Sn-9Cu+-Zn (I+S)

5. Effects of Elements in Dental Amalgam Alloys:
   a. **Ag**: Primary reactant with Hg to cause setting
   b. **Sn**: Produces solubility and fluidity for mixture
   c. **Cu**: Reacts with tin to improve corrosion resistance
   d. **Zn**: Processing aid (oxygen scavenger) to suppress oxidation of Ag, Sn, and Cu during melting for alloying.

   (Zn also appears to affect long term corrosion resistance.)
DENTAL AMALGAM STRUCTURE:

A. Dental Amalgam Reactions:

1. Overview of the Process:
   a. MUCH MORE POWDER used than can react completely
   b. SURFACES of alloy particles dissolve into mercury.
   c. SURFACES of particles penetrated by mercury.
   d. After trituration the reaction products NUCLEATE AND GROW on particles.
   e. Continued reaction transforms the plastic mass into a solid.
   f. Unreacted (RESIDUAL) alloy particles suspended in reaction product matrix.

2. Schematic of Chemical Reactions during Setting:
   a. **Low Copper** Dental Amalgam (Conventional Dental Amalgam; eg, Velvalloy):

   \[
   [\text{Ag-Sn}] + [\text{Hg}] \rightarrow \gamma_1 [\text{Ag-Sn}] + [\text{Ag-Hg}] + [\text{Sn-Hg}] 
   \]

   ![Diagram of Low Copper Amalgam reactions]

   b. **High Copper** Dental Amalgam:

   (1) **Two Particle** System: (eg, Dispersalloy)

   \[
   [\text{Ag-Sn}] + [\text{Ag-Cu}] + [\text{Hg}] \rightarrow \gamma_1 [\text{Ag-Sn}] + [\text{Ag-Cu}] + [\text{Ag-Hg}] + [\text{Sn-Hg}] 
   \]

   \[
   \rightarrow \gamma_2 [\text{Ag-Sn}] + [\text{Ag-Cu}] + [\text{Ag-Hg}] + [\text{Cu-Sn}] 
   \]

   ![Diagram of High Copper Amalgam reactions (Two Particle System)]

   (2) **One Particle** System: (eg, Tytin)

   \[
   \frac{[\text{Ag-Sn-Cu}]}{\text{Alloy}} + [\text{Hg}] \rightarrow \gamma_1 \frac{[\text{Ag-Sn-Cu}]}{\text{Alloy}} + [\text{Ag-Hg}] + [\text{Sn-Hg}] 
   \]

   \[
   \rightarrow \gamma_2 \frac{[\text{Ag-Sn-Cu}]}{\text{Alloy}} + [\text{Ag-Hg}] + [\text{Cu-Sn}] 
   \]

   ![Diagram of High Copper Amalgam reactions (One Particle System)]
B. Dental Amalgam Phase Diagrams for Reference to Chemical Reactions:

1. Starting components:
   a. Ag-Sn Irregular Particles or Spheres = gamma (γ)
   b. Ag-Cu Irregular Particles or Spheres = alloy (A)

2. Reaction Products:
   a. Ag-Hg Crystals in Matrix = gamma-1 (γ₁)
   b. Sn-Hg Crystals in Matrix = gamma-2 (γ₂)
   c. Cu₅Sn₃ Crystals in Matrix = epsilon (ε)
   d. Cu₃Sn Crystals Near Particles = eta (η)
DENTAL AMALGAM MANIPULATION:

A. Product Selection Considerations:

1. Corrosion Resistance:
   a. More Ductile, Better Edge Strength = Low Copper
   b. More Corrosion Resistant = High Copper
2. Mechanical Strength:
   a. High initial strength = Spherical High Copper
   b. High final strength = Spherical High Copper
3. Handling Characteristics:
   a. More Fluidity = Spherical Particles
   b. More resistance for condensation = Irregular Particles
4. Reaction Characteristics:
   a. Setting Time: = Slow (Student Set), Regular, Fast
   b. Carving Time: = ????
   c. Polishability: = ????

<table>
<thead>
<tr>
<th>Placement, Condensation</th>
<th>Carving, Burnishing</th>
<th>Polishing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset of MIXING</td>
<td>End of MIXING</td>
<td>Start of SETTING</td>
</tr>
</tbody>
</table>

B. Proportioning and Handling:

1. Check Product Age:
   a. Shelf life of amalgam alloy (~1y); Aging slows reaction (slower setting)
   b. Product Age = Current Date - Manufacture Date
   Batch (or Lot) Number = Reverse Code for Manufacturing Date
   041501 = Manufactured on 01-15-2004
   c. Expiration Date = Do not use after this data (e.g., ESP = 01-2005)

2. Amalgam Hygiene:
   a. Do NOT contact the alloy or mercury with your skin.
   b. PROTECT against spillage during triturations.
   c. Do NOT DISCARD SCRAP materials into waste containers.
   d. COLLECT all scrap and store under water or photographic fixer solutions in closed container for periodic recycling.
   e. Utilize mercury DOSIMETERS, badges, or lab tests for routine dental personal and office testing.

3. Proportion Materials:
   a. Select proper Hg/alloy ratio, or
   b. Select pre-capsulated materials. (L= 42-to-48 wt. %)
4. Amalgamator ENERGY $\propto$ (equipment type), (speed), (time)
   a. Amalgamator : Caulk VariMix II or III
   b. Amalgamation Speed: Select Low-Medium-High
   b. Amalgamation Time: Set secs on Caulk Vari-Mix II or III

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<table>
<thead>
<tr>
<th>Amalgam</th>
<th>Speed:</th>
<th>Time:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersalloy</td>
<td>M-2,</td>
<td>13 secs</td>
</tr>
<tr>
<td>Tytin</td>
<td>M-2,</td>
<td>4-5 secs</td>
</tr>
<tr>
<td>Sybraloy</td>
<td>M-2,</td>
<td>13 secs</td>
</tr>
<tr>
<td>Spheralloy</td>
<td>M-2,</td>
<td>15 secs</td>
</tr>
<tr>
<td>Valiant</td>
<td>M-2,</td>
<td>13 secs</td>
</tr>
<tr>
<td>Valiant PhD</td>
<td>M-2,</td>
<td>15 secs</td>
</tr>
<tr>
<td>Velvalloy</td>
<td>M-2,</td>
<td>20 secs</td>
</tr>
</tbody>
</table>

   c. Check for proper amalgamator operation with test run.
   d. Insert capsule, close safety cover, and start amalgamator.

5. Visually Analyze Amalgam Mixture:
   a. Open capsule and remove any mixing pestles with tweezers.
   b. Empty mixture from capsule into a dappen dish.
   c. Inspect the amalgam mass:
      (1) Under-triturated = Grainy, Dull
      (2) Properly Triturated = Coherent Mass, Smooth
      (3) Over-triturated: = Grainy

6. Placement and Condensation of Amalgam:
   a. Condense in overlapping strokes
   b. Remove mercury rich matrix that is expressed
   c. Condensation pressure increases with smaller tip condensers:

   Stress = Load/Area = (Your Push)/(Condenser Tip)

   Spherical amalgams are lower viscosity and more difficult to condense but have
   less initial mercury.

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<table>
<thead>
<tr>
<th>LOAD Required Per Condenser TIP Diameter (mm):</th>
<th>Generated Condensation Stress (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8 1.0 1.5 1.75 2.0 2.5</td>
<td>STRESS (MPa)</td>
</tr>
<tr>
<td>1.0  1.6 3.5 4.8 6.3 9.8 &gt;&gt;&gt;&gt;&gt; 2.0</td>
<td></td>
</tr>
<tr>
<td>1.3  2.0 4.4 6.0 7.8 12. &gt;&gt;&gt;&gt;&gt; 2.5</td>
<td></td>
</tr>
<tr>
<td>2.7  4.2 9.4 13. 17. 26. &gt;&gt;&gt;&gt;&gt; 5.3</td>
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</tr>
<tr>
<td>4.5  7.1 16. 22. 28. 44. &gt;&gt;&gt;&gt;&gt; 9.</td>
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<tr>
<td>7.   11. 25. 34. 44. 69. &gt;&gt;&gt;&gt;&gt; 14.</td>
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<tr>
<td>28.  44. 99. 135. 176. 275. &gt;&gt;&gt;&gt;&gt; 56.</td>
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   d. Well-condensed amalgams contain less matrix and perform better!
C. **Dimensional Change During Setting:**

1. **Mechanisms:**
   a. CONTRACTION during alloy dissolution
   b. EXPANSION during impingement of expanding edges of particles

2. **Dimensional Changes During Setting:**
   a. ADA Limit for contraction or expansion = <20 μm/cm
   b. Actual expansion/contraction observed depends when you start to measure

3. **Influence of Reaction Variables:**
   a. Alloy Particle Size and Shape:
   b. Initial Hg/Alloy Ratio:
   c. Trituration Time:
   d. Condensation Method:
   e. Moisture Contamination:
      Produces secondary expansion: \( \text{Zn} + \text{H}_2\text{O} \rightarrow \text{ZnO} + \text{H}_2 \text{ (gas)} \)
DENTAL AMALGAM PROPERTIES:

A. Introduction:

1. Specifications for Dental Amalgam Properties:
   a. ADA = Old Spec. No. 1 for Alloy for Dental Amalgam = Old Spec. No. 6 for Dental Mercury (for Amalgam)
   b. ISO = same as ADA/ANSI

2. Clinical Performance of Dental Amalgam:
   a. Longevity:
      (1) Low Copper = 8-12 yrs 4-5 yrs
      (2) High Copper = 20-25 yrs 8-12 yrs
   b. Modes of Failure:
      (1) Low Copper: Caries > Marginal Fracture > Bulk Fracture
      (2) High Copper: Bulk Fracture > Marginal Fracture > Caries

B. Physical Properties of Interest:

1. Thermal Conductivity: too high for pulpal protection
2. Electrical Conductivity: too high
3. Coef of Thermal Exp/Cont: too high (tooth = 9-11 vs amalgam = 25 ppm/C)
4. Radiopacity: too high (just want enough to see caries)

C. Mechanical Properties of Interest:

1. Compressive Strength:
   a. Low Copper Dental Amalgam = 55,000 psi (380 MPa)
   b. High Copper Dental Amalgam = 65,000 psi (414 MPa)
2. Tensile Strength:
   a. Low Copper Dental Amalgam = 8,000 psi
   b. High Copper Dental Amalgam = 7,000 psi but tends to be BRITTLE
3. ADA Static Creep: (% change for hardened amalgam under load for 5 hrs)
   a. Low Copper Dental Amalgam = 1-3%
   b. High Copper Dental Amalgam = <1%
4. ADA Flow: (% change from 3 to 24 hrs/ really a setting time test)
   a. Low Copper Dental Amalgam = 1%
   b. High Copper Dental Amalgam = <1%

<table>
<thead>
<tr>
<th></th>
<th>Compressive Strength (psi)</th>
<th>Tensile Strength (psi)</th>
<th>CREEP: %,24-hr</th>
<th>FLOW: %,24-hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15-min 1-hr 24-hr</td>
<td>15-min 1-hr 24-hr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Copper:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velvalloy (I)</td>
<td>5,400 17,400 56,200</td>
<td>625 1,900 9,000</td>
<td>1.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Spheraloy (S)</td>
<td>5,800 18,500 56,900</td>
<td>450 1,550 8,800</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>High Copper:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optalloy II (I+S)</td>
<td>9,000 23,800 55,900</td>
<td>1,000 2,350 7,250</td>
<td>1.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Dispersalloy (I+S)</td>
<td>6,200 22,400 59,900</td>
<td>575 1,750 6,990</td>
<td>0.25</td>
<td>0.7</td>
</tr>
<tr>
<td>Indiloy (S)</td>
<td>4,600 26,300 64,500</td>
<td>450 2,400 6,500</td>
<td>0.22</td>
<td>0.5</td>
</tr>
<tr>
<td>Sybraloy (S)</td>
<td>23,800 50,000 72,700</td>
<td>2,190 4,700 6,600</td>
<td>0.05</td>
<td>0.3</td>
</tr>
<tr>
<td>Tytin (S)</td>
<td>10,200 40,800 79,100</td>
<td>990 4,000 9,300</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* J Dent Res, Nov-Dec 1978
D. **Chemical Properties:**

1. **Chemical Corrosion** (Tarnish): does not create problems
   a. Reaction:
      
      (1) Low Copper:
      \[
      \text{Ag}^{+1} + S^{-2} \rightarrow \text{Ag}_2S \quad \text{(black film)}
      \]

      (2) High Copper:
      \[
      \text{Ag}^{+1}_2 + S^{-2} \rightarrow \text{Ag}_2S \quad \text{(black film)}
      \]
      \[
      \text{Cu}^{+2} + ????? \rightarrow ????? \quad \text{(green film)}
      \]

   b. No known bio-hazards or problems for amalgams other than the fact that the films are not esthetic

2. **Electrochemical Corrosion:**
   a. Types: (all occur at same time)
      
      (1) Galvanic Corrosion: (e.g., restoration touching Au crown)
      (2) Structure-Sensitive Corrosion: (local galvanic corrosion)
      (3) Crevice Corrosion: (concentration cell corrosion)
      (4) Stress Corrosion:

   b. Corrosion Reactions for Dental Amalgam Phases:
      
      (1) Low Copper Dental Amalgam:
      \[
      [\text{Sn-Hg}] \rightarrow [\text{Sn}] + \text{saliva} \rightarrow [\text{Sn-O-Cl}] \quad \text{(soluble)}
      \rightarrow [\text{Sn}] + \text{saliva} \rightarrow [\text{Sn-O}] \quad \text{(insoluble)}
      \rightarrow [\text{Hg}] + [\text{Ag-Sn}] \rightarrow [\text{Ag-Hg}] + [\text{Sn-Hg}]
      \]
      
      **Penetrating Corrosion:** interconnected \( \frac{1}{2} \) crystals lost.
      Amalgam becomes progressively spongy.
      Interior coated with insoluble Sn-O (SnO and SnO\(_2\)).
      Margins occluded with insoluble SnO crystals.

      (2) High Copper Dental Amalgam:
      \[
      [\text{Cu-Sn}] \rightarrow [\text{Sn}] + \text{saliva} \rightarrow [\text{Sn-O-Cl}] \quad \text{(soluble)}
      \rightarrow [\text{Sn}] + \text{saliva} \rightarrow [\text{Sn-O}] \quad \text{(insoluble)}
      \rightarrow [\text{Cu}] + \text{saliva} \rightarrow [\text{Cu-Cl}] \quad \text{(soluble)}
      \]
      
      **Superficial Corrosion:** Cu-Sn crystals not connected.
      Only the surfaces tend to corrode.
      Margins occluded by insoluble Sn-O crystals.
E. **Biological Properties:**

1. **Mercury Toxicity:** minute and transient releases- not at toxic levels
   a. OSHA maximum TLV = 50 μg/m³ (vapor)
   b. Transient intraoral release = < 35 μg/m³ (during mastication)

2. **Mercury Hypersensitivity:** <1/100,000,000 during insertion or removal
   a. Low level allergic reaction.
   b. Controllable with anti-histamine pre-medication, rubber dam, and high volume air and water evacuation.

3. **Amalgam Tattoo:**
   a. May occur during amalgam removal when a rubber dam is NOT used and particles of amalgam are flung by the bur into the gingival tissues where they remain embedded, become fibrous tissue encapsulated, and corrode to form black corrosion products.
   b. No known adverse reactions but esthetically unpleasing.

F. **Clinical Performance: Reasons for Failure**

1. **Secondary Dental Caries:**
   a. Principally with low copper amalgams with significant corrosion
   b. Generally occurs at proximal margins

2. **Marginal Fracture:**
   a. Much more prevalent in low copper dental amalgams
   b. Related to corrosion-creep and mechanical FATIGUE

   \[ \text{Jorgensen theory of mercuroscopic expansion} \]

   theory for corrosion-creep

   Creep and expansion

   Enamel

   Marginal fracture

   Amalgam

   Chewing produces marginal fractures

   Mahler scale is used to rate marginal fracture

   **Mahler scale** for rating degree of marginal fracture

   \[
   \text{GOOD} \quad \text{> OK} \quad \text{> FAILURE}
   \]

3. **Bulk Fracture:**
   a. Related to traumatic occlusion or fatigue fracture
   b. More common in narrow or thin amalgam isthmus
   c. **Predominant failure in high copper amalgams**
MULTIPLE CHOICE STUDY QUESTIONS:

Dental amalgam is defined as:
- a. A mixture of mercury with any metal
- b. A mixture of mercury with silver
- c. A mixture of mercury with silver and tin
- d. A mixture of mercury with any zinc alloy
- e. The alloy for mixing with mercury

How much mercury (by weight) is in a modern set dental amalgam?
- a. >60%
- b. 55-60%
- c. 50-55%
- d. 45-50%
- e. 40-45%

What is the copper content in low copper dental amalgam alloys?
- a. 0 - 5%
- b. 5 - 12%
- c. 12 - 30%
- d. 30 - 38%
- e. 38 - 50%

What components are typical in low copper dental amalgam alloy?
- a. Ag-Sn
- b. Ag-Sn-(Cu)-(Zn)
- c. Sn-Cu-Zn
- d. Ag-Sn-Cu-(Zn)
- e. Ag-Sn-Cu-Zn

What components are typical of high copper dental amalgam alloy?
- a. Ag-Sn-Cu
- b. Ag-Sn-Cu-(Zn)
- c. Ag-Sn-Zn
- d. Ag-Sn
- e. Sn-Cu-Zn

Which one of the following terms is not synonymous with the rest in the list?
- a. Comminuted particles
- b. Filings
- c. Lathe-cut particles
- d. Irregular particles
- e. Spherical particles

Comminution is:
- a. Milling or filing an ingot into powder particles
- b. Heat treatment to control the setting reaction of powder particles
- c. Decreasing the mercury content of an amalgam
- d. Eliminating the copper content of an amalgam alloy
- e. Elimination of the tarnish on an amalgam restoration
SPHERICAL dental amalgam alloy particles are generally produced by:
   a. Liquid alloy atomization
   b. Flame melting of lathe cut particles
   c. Vitrification of lathe cut particles
   d. Comminution
   e. Heat treating lathe cut particles

Which one of the following is NOT a standard method of classification for dental amalgams?
   a. Particle Shape
   b. Copper Content
   c. Zinc Content
   d. Number of Powder Particles
   e. Mercury Content

DISPERSALLOY dental amalgam alloy is made as what type of powder?
   a. Irregular
   b. Irregular + Irregular
   c. Irregular + Spherical
   d. Irregular + Spherical
   e. Spherical

TYTIN dental amalgam alloy is made as what type of powder?
   a. Irregular
   b. Irregular + Irregular
   c. Irregular + Spherical
   d. Spherical + Spherical
   e. Spherical

SYBRALOY dental amalgam alloy is made as what type of powder?
   a. Irregular
   b. Irregular + Irregular
   c. Irregular + Spherical
   d. Spherical + Spherical
   e. Spherical

NEW TRUE DENTALLOY dental amalgam alloy is made as what type of powder?
   a. Irregular
   b. Irregular + Irregular
   c. Irregular + Spherical
   d. Spherical + Spherical
   e. Spherical

Which one of the following is a HIGH COPPER dental amalgam alloy?
   a. Velvalloy
   b. Caulk Spherical
   c. Shofu Spherical
   d. Dispersalloy
   e. New True Dentalloy

Which one of the following is a LOW COPPER dental amalgam alloy?
   a. Tytin
   b. Sybralloy
   c. New True Dentalloy
   d. Dispersalloy
   e. Aristalloy CR
What is the reason Zn is used in a dental amalgam alloy?
   a. Oxygen scavenger in production
   b. Reducing mercury vapor release from the set restoration
   c. Improved hardness
   d. Controlling the setting reaction
   e. Prevent tarnishing

What is the reason Sn is included in a dental amalgam alloy?
   a. Corrosion protection
   b. Improved ductility
   c. Prevent tarnishing
   d. Increased tensile strength
   e. Particle dissolution during reaction

What is the reason Cu is included in a dental amalgam alloy?
   a. Corrosion protection
   b. Increased ductility
   c. Prevention of tarnishing
   d. Reduction in amalgamation speed
   e. Improved condensability

The SETTING REACTION of dental amalgam proceeds primarily by:
   a. Dissolution of the entire alloy particle into mercury
   b. Dissolution of the Cu from the particles into mercury
   c. Mercury reaction with Ag on or in the alloy particle
   d. Formation of Zn-Hg crystals
   e. Precipitation of Sn-Hg crystals

What is the ABBREVIATION for the Ag-Sn phase?
   a. Gamma (\( \gamma \))
   b. Gamma-1 (\( \gamma_1 \))
   c. Gamma-2 (\( \gamma_2 \))
   d. Eta (\( \eta \))
   e. Epsilon (\( \varepsilon \))

What is the ABBREVIATION for the Ag-Hg phase?
   a. Gamma (\( \gamma \))
   b. Gamma-1 (\( \gamma_1 \))
   c. Gamma-2 (\( \gamma_2 \))
   d. Eta (\( \eta \))
   e. Beta (\( \beta \))

What is the ABBREVIATION for the Sn-Hg phase?
   a. Gamma (\( \gamma \))
   b. Gamma-1 (\( \gamma_1 \))
   c. Gamma-2 (\( \gamma_2 \))
   d. Beta (\( \beta \))
   e. Epsilon (\( \varepsilon \))

Which phase in a set dental amalgam contains most of the MERCURY?
   a. Gamma (\( \gamma \))
   b. Gamma-1 (\( \gamma_1 \))
   c. Gamma-2 (\( \gamma_2 \))
   d. Eta (\( \eta \))
   e. Epsilon (\( \varepsilon \))
Which one of the following is responsible for CONTRACTION during the dental amalgam setting reaction?

a. Cooling of the amalgam mixture after trituration
b. Settling of the particles in the fluid matrix
c. Higher density of the product phases versus reactant phases
d. Loss of mercury due to vaporization
e. Mercury penetration into the pores of the powder particles

Which one of the following is responsible for EXPANSION during the dental amalgam setting reaction?

a. Lower density of the product versus reactant phases
b. Impingement of Ag-Hg crystals in matrix during growth
c. Increased temperature of the mass due to exothermic heat
d. Dissolution of selective components out of the particles
e. Formation of by-product gases during the reaction

What is the ADA LIMIT for expansion or CONTRACTION during the setting of dental amalgam?

a. <1 μm/cm
b. <20 μm/cm
c. <50 μm/cm
d. <100 μm/cm
e. <250 μm/cm

Which one of the following variables does NOT influence the amount of DIMENSIONAL CHANGE during setting of dental amalgams?

a. Alloy particle size or shape
b. Hg/alloy ratio
c. Trituration time
d. Condensation method
e. Burnishing technique

What does the batch (or lot) number code of “040501” on an amalgam alloy mean?

a. It was produced on January 5, 2004
b. It was shipped on January 5, 2004
c. It is no longer acceptable after January 5, 2004
d. That it contains 4Sn-5Cu-1Zn in the alloy
e. That it should not be used before January 5, 2004

The amalgamator SETTING for SYBRALLOY alloy on a Caulk Vari-Mix II is:

a. L-1 setting, 20 secs
b. M-1 setting, 20 secs
c. M-2 setting, 3 secs
d. M-2 setting, 13 secs
e. H-3 setting, 5 secs

A PROPERLY TRITURATED dental amalgam mixture should look like a:

a. Grainy, dull mass
b. Coherent, smooth mass
c. Grainy, wet mixture
d. Fibrous, dull mass
e. Fibrous, shiny mass
Which one of the following produces the MOST mercury-rich matrix removal?
   a. Condensation late in the working time
   b. Use of the largest condenser tip
   c. Use of the most load during condensation
   d. Non-overlapping condensing strokes
   e. Burnishing

What is the CL<sub>50</sub> for LOW COPPER dental amalgams?
   a. 1-2 years
   b. 4-5 years
   c. 8-12 years
   d. 20-25 years
   e. 30-50 years

What is the CL<sub>50</sub> for HIGH COPPER dental amalgams?
   a. 1-2 years
   b. 4-5 years
   c. 8-12 years
   d. 20-25 years
   e. 30-50 years

What is the effectiveness for HIGH COPPER dental amalgams?
   a. 1-2 years
   b. 4-5 years
   c. 8-12 years
   d. 20-25 years
   e. 30-50 years

Which one of the following mechanisms of FAILURE is most common for LOW COPPER dental amalgam?
   a. Excessive tarnish
   b. Bulk fracture
   c. Intergranular corrosion of the occlusal surface
   d. Dental caries
   e. Marginal fracture

Which one of the following mechanisms of FAILURE is most common for HIGH COPPER dental amalgam?
   a. Excessive tarnish
   b. Bulk fracture
   c. Intergranular corrosion of the occlusal surface
   d. Enamel wall fracture from thermal expansion stresses
   e. Marginal fracture

What is the typical COMPRESSIVE strength (after 24 hrs) for HIGH COPPER amalgam?
   a. 25,000 psi
   b. 35,000 psi
   c. 45,000 psi
   d. 55,000 psi
   e. 65,000 psi
What is the PERCENTAGE of the final strength (24-hr) is developed by a newly placed (15-min) dental amalgam?
   a. <40 %
   b. 40-60 %
   c. 60-80 %
   d. 80-95 %
   e. 95-98 %

Which one of the following amalgams displays the HIGHEST EARLY STRENGTH?
   a. Irregular particle low copper amalgam
   b. Spherical particle low copper amalgam
   c. Irregular particle high copper amalgam
   d. Irregular + spherical particle high copper amalgam
   e. Spherical particle high copper amalgam

MARGINAL FRACTURE of dental amalgam is NOT associated with this property.
   a. Compressive strength
   b. Creep
   c. Mercury content
   d. Electrochemical properties
   e. Thermal conductivity

Which one of the following MECHANICAL PROPERTIES is the most important in determining the resistance to marginal fracture?
   a. Compressive Strength
   b. Tensile Strength
   c. Shear Strength
   d. Flexural Strength
   e. Brittleness

Which one of the following does NOT affect the strength of dental amalgam?
   a. Time between trituration and condensation
   b. Mercury content
   c. Zinc content
   d. Condensation effectiveness
   e. Porosity

What is the CREEP value for most HIGH COPPER dental amalgams?
   a. 10%
   b. 5-10%
   c. 1-5%
   d. <1%
   e. 0%

The CREEP value of LOW COPPER dental amalgams correlates with:
   a. Marginal fracture
   b. Bulk fracture
   c. Tensile strength
   d. Setting time
   e. Burnishability
Which one of the following INTRAORAL IONS is primarily responsible for amalgam TARNISH?

- a. Cl
- b. S
- c. Na
- d. K
- e. O

Which one of the ELEMENTS in dental amalgam is primarily responsible for TARNISH?

- a. Silver
- b. Tin
- c. Zinc
- d. Mercury
- e. Copper

What type of electrochemical CORROSION is MOST COMMON at the margins of dental amalgam?

- a. Galvanic corrosion
- b. Structure-sensitive corrosion (local galvanic corrosion)
- c. Crevice corrosion (concentration cell corrosion)
- d. Intergranular corrosion
- e. Stress corrosion

In LOW COPPER dental amalgams, which phase is the MOST ANODIC?

- a. Gamma (\(\gamma\))
- b. Gamma-1 (\(\gamma_1\))
- c. Gamma-2 (\(\gamma_2\))
- d. Eta (\(\eta\))
- e. Epsilon (\(\varepsilon\))

During electrochemical corrosion of LOW COPPER dental amalgam, which corrosion product which forms is INSOLUBLE?

- a. Sn-O
- b. Sn-O-Cl
- c. Sn-Cl
- d. Ag-Cl
- e. Cu-Sn

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- a. Gamma (\(\gamma\))
- b. Gamma-1 (\(\gamma_1\))
- c. Gamma-2 (\(\gamma_2\))
- d. Eta (\(\eta\))
- e. Beta (\(\beta\))
Which alloy pair produces the MOST POWERFUL GALVANIC corrosion couple?
- a. Dental gold casting alloy / Conventional Dental Amalgam
- b. Conventional Dental Amalgam / High Copper Dental Amalgam
- c. Gamma Phase / Gamma One Phase
- d. Spherical High Copper Amalgam / Irregular High Copper Amalgam

PENETRATING CORROSION occurs in:
- a. Low copper dental amalgams because gamma-2 corrodes
- b. Low copper dental amalgams because gamma-1 corrodes
- c. High copper dental amalgams because gamma-2 corrodes
- d. High copper dental amalgams because gamma-1 corrodes
- e. High copper dental amalgams because eta corrodes

SUPERFICIAL CORROSION occurs in:
- a. Low copper dental amalgams because gamma-2 corrodes
- b. Low copper dental amalgams because gamma-1 corrodes
- c. High copper dental amalgams because gamma-2 corrodes
- d. High copper dental amalgams because gamma-1 corrodes
- e. High copper dental amalgams because eta corrodes

During the corrosion of LOW COPPER dental amalgam, which one of the following components may be LOST from the restoration?
- a. Silver
- b. Tin
- c. Copper
- d. Mercury
- e. Zinc

During the corrosion of HIGH COPPER dental amalgams, which one of the following elements may be LOST from the restoration?
- a. Silver
- b. Tin
- c. Copper
- d. Mercury
- e. Zinc

Mercury vapor limits (TLV) are defined by OSHA as:
- a. <1 μg/m³
- b. <10 μg/m³
- c. <25 μg/m³
- d. <50 μg/m³
- e. <90 μg/m³

Mercury vapor produces HYPERSENSITIVITY reactions in:
- a. <1/1,000,000 people
- b. <1/500,000 people
- c. <1/100,000 people
- d. <1/1,000 people
- e. <1/100 people

Jorgensen explained the production of MARGINAL FRACTURE in terms of:
- a. Expansion during setting
- b. Ductility of amalgam margins
- c. Expansion and contraction stresses
- d. Mechanical fatigue
- e. Mercuroscopic expansion
SPHERICAL HIGH COPPER dental amalgams (vs low copper types) have:
  a. Better edge strength
  b. Better condensability
  c. Better ductility
  d. Higher initial strength
  e. Lower corrosion resistance

**DISCUSSION STUDY QUESTIONS:**

- Which portions of a Class II dental amalgam restoration will be mechanically the weakest?
- Explain why TYTIN amalgams might be more sensitive to temperature or galvanism immediately after insertion.
- Should dental amalgams be polished during oral prophylaxes? Why?
- What special precautions should be taken during the removal of a corroded dental amalgam restoration?
- Why do Class V amalgams seem to be more tarnished than Class I amalgams?
- A patient complains of ringing in his ear due to the contact of a new crown with an adjacent Class II amalgam. Explain what you would do to test whether this was true and how you would manage the situation.
- Explain why spherical dental amalgams tend to have higher strengths than those based on irregular particles?
- A general practitioner who has been in practice for 35 years, says that the average age of the low copper amalgam restorations in his patients is 20 years. Explain why this is true despite the CL50 values for those amalgams.
- Explain the dilemma for using a small diameter condenser with a spherical alloy amalgam.
- What are the clinical indications for the replacement of a dental amalgam restoration? What is the accuracy of each one of those indications?
- On a D-O amalgam restoration, explain the relative susceptibility of the margins to marginal fracture.